IEEE 802.3 Ethernet

www.ieee802.org/3/

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Before I Share My Opinion…

“At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position, explanation, or interpretation of the IEEE.”

IEEE-SA Standards Board Operation Manual (subclause 5.9.3)
Agenda

IEEE 802.3 Overview

IEEE 802.3 Ethernet Physical Layers
Rate, distance, media

IEEE 802.3 Ethernet emerging technologies
New physical layers, new technologies

Conclusion
Agenda

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Conclusion
IEEE Std 802.3 Frame format

Size (Octets)

- 7: Preamble
- 1: SFD
- 6: DA
- 6: SA
- 2: Length/Type
- 46 to 1500 or 1504 or 1982 bytes of Client Data
- Frame
- Packet
- 4: FCS
- Extension

Key:
- SFD – Start frame delimiter
- DA – Destination address
- SA – Source address
- MAC – Medium access control
- FCS – Frame check sequence
IEEE Std 802.3 layer diagram
1Mb/s and 10Mb/s

OSI Reference model layers

Application
Presentation
Session
Transport
Network
Data link
Physical

Higher layers
LLC or other MAC client
MAC control
MAC
PLS
PMA

Key:
LLC – Logical link control
MAC – Medium access control
PLS – Physical layer signalling
AUI – Attachment unit interface
MAU – Medium attachment unit
PMA – Physical medium attachment
MDI – Media dependant interface

Medium
AUI
MAU
MDI
MDI

IEEE 802
Version 1.1
IEEE 802 March 2011 workshop
Page 6
IEEE Std 802.3 layer diagram
100Mb/s and above

OSI Reference model layers

- Application
- Presentation
- Session
- Transport
- Network
- Data link
- Physical

Higher layers

- LLC or other MAC client

MAC control

MAC

RS

PCS

FEC

PMA

PMD

AN

Medium

xMII

MDI

Key:
- LLC – Logical link control
- MAC – Medium access control
- RS – Reconciliation sublayer
- xMII – Medium independent interface
- PHY – Physical layer device
- PCS – Physical coding sublayer
- FEC – Forward error correction
- PMA – Physical medium attachment
- PMD – Physical medium dependent
- MDI – Media dependent interface
- AN – Auto-Negotiation

Notes:
1 – Optional or omitted depending on PHY Type
2 – Conditional based on PHY Type

xMII:
- MII – 100Mb/s Medium independent interface
- GMII – 1 Gb/s Medium independent interface
- XGMII – 10 Gb/s Medium independent interface
- XLGMI – 40 Gb/s Medium independent interface
- CGMII – 100 Gb/s Medium independent interface
Agenda

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Rate, distance, media

IEEE 802.3 Ethernet emerging technologies
New physical layers, new technologies

Conclusion
# 10Mb/s and 100 Mb/s Ethernet

<table>
<thead>
<tr>
<th>PHY Type</th>
<th>Data rate</th>
<th>Distance</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE Std 802.3-1985 Ethernet MAC, 10BASE5</td>
<td>10Mb/s</td>
<td>500m</td>
<td>Coaxial</td>
</tr>
<tr>
<td>10BASE5</td>
<td>10Mb/s</td>
<td></td>
<td>Coaxial</td>
</tr>
<tr>
<td>IEEE Std 802.3c-1985 Repeater, FOIRL</td>
<td>FOIRL</td>
<td>1km</td>
<td>Two multimode</td>
</tr>
<tr>
<td>IEEE Std 802.3a-1988 10BASE2</td>
<td>10BASE2</td>
<td>185m</td>
<td>Coaxial</td>
</tr>
<tr>
<td>10BASE2</td>
<td>10Mb/s</td>
<td></td>
<td>Coaxial</td>
</tr>
<tr>
<td>IEEE Std 802.i-1990 10BASE-T</td>
<td>10BASE-T</td>
<td>100m</td>
<td>Twisted-pair</td>
</tr>
<tr>
<td>IEEE Std 802.3j-1993 10BASE-F</td>
<td>10BASE-FP</td>
<td>1km</td>
<td>Two multimode</td>
</tr>
<tr>
<td>10BASE-FP</td>
<td>10Mb/s</td>
<td></td>
<td>Coaxial</td>
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<tr>
<td>10BASE-FL</td>
<td>10Mb/s</td>
<td>2km</td>
<td>Two multimode</td>
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<tr>
<td>10BASE-FB</td>
<td>10Mb/s</td>
<td>2km</td>
<td>Two multimode</td>
</tr>
<tr>
<td>IEEE Std 802.3u-1995 100BASE-T</td>
<td>100BASE-TX</td>
<td>100m</td>
<td>2 pair Cat 5</td>
</tr>
<tr>
<td>100BASE-TX</td>
<td>100Mb/s</td>
<td></td>
<td>2 pair Cat 5</td>
</tr>
<tr>
<td>100BASE-T4</td>
<td>100Mb/s</td>
<td>100m</td>
<td>4 pair Cat 3</td>
</tr>
<tr>
<td>100BASE-FX</td>
<td>100Mb/s</td>
<td>2Km</td>
<td>Two multimode</td>
</tr>
<tr>
<td>IEEE Std 802.3x-1997 Full Duplex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IEEE Std 802.3y-1997 100BASE-T2</td>
<td>100BASE-T2</td>
<td>100m</td>
<td>2 pair Cat 3</td>
</tr>
<tr>
<td>100BASE-T2</td>
<td>100Mb/s</td>
<td></td>
<td>2 pair Cat 3</td>
</tr>
</tbody>
</table>

![Graph showing data rates and distances](image)

**Key:**
- Backplane
- Co-axial
- Twin-axial
- Twisted pair
- Multimode Fibre
- Single-mode Fibre
- Voice grade copper
- Point to Multipoint Fibre
Topology evolution

IEEE Std 802.i-1990 10BASE-T
IEEE Std 802.3j-1993 10BASE-F

IEEE Std 802.3u-1995 100BASE-T
IEEE Std 802.3x-1997 Full Duplex
TIA/EIA 568:1991 Structured building wiring
ISO/IEC 11801:1995 Structured building wiring

Key:
- Collision domain
- 10BASE2/10BASE5
- 10BASE-T link
- 10BASE-F link
- 100BASE-F link
# 1Gb/s and 10 Gb/s Ethernet

<table>
<thead>
<tr>
<th>PHY Type</th>
<th>Data rate</th>
<th>Distance</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE Std 802.3z-1998</td>
<td>1 Gb/s</td>
<td>220m</td>
<td>Two multimode fibres</td>
</tr>
<tr>
<td>1000BASE-SX</td>
<td>1Gb/s</td>
<td>220m</td>
<td>Two multimode fibres</td>
</tr>
<tr>
<td>1000BASE-LX</td>
<td>1Gb/s</td>
<td>5Km</td>
<td>Two single-mode Two multimode</td>
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<tr>
<td>1000BASE-CX</td>
<td>1Gb/s</td>
<td>25m</td>
<td>Copper cable assembly</td>
</tr>
<tr>
<td>IEEE Std 802.3ab-1999, 1000BASE-T</td>
<td>1Gb/s</td>
<td>100m</td>
<td>Twisted-pair</td>
</tr>
<tr>
<td>1000BASE-T</td>
<td>1Gb/s</td>
<td>100m</td>
<td>Twisted-pair</td>
</tr>
<tr>
<td>IEEE Std 802.3ad-2000 Link Aggregation</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>10GBASE-SR/W</td>
<td>10Gb/s</td>
<td>33m</td>
<td>Two multimode</td>
</tr>
<tr>
<td>10GBASE-LX4</td>
<td>10Gb/s</td>
<td>10Km</td>
<td>Two single-mode Two multimode</td>
</tr>
<tr>
<td>10GBASE-LR/W</td>
<td>10Gb/s</td>
<td>10Km</td>
<td>Two single-mode</td>
</tr>
<tr>
<td>10GBASE-ER/W</td>
<td>10Gb/s</td>
<td>40Km</td>
<td>Two single-mode</td>
</tr>
</tbody>
</table>

### Diagram

![Diagram of Ethernet distances and rates](attachment:image_url)

**Key:**
- **- Backplane**
- **- Co-axial**
- **- Twin-axial**
- **- Twisted pair**
- **- Multimode Fibre**
- **- Single-mode Fibre**
- **- Voice grade copper**
- **- Point to Multipoint Fibre**
## Ethernet in the First Mile

<table>
<thead>
<tr>
<th>PHY Type</th>
<th>Data rate</th>
<th>Distance</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE Std 802.3ah-2004 Ethernet in the First Mile</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100BASE-LX10</td>
<td>100Mb/s</td>
<td>10Km</td>
<td>Two single-mode</td>
</tr>
<tr>
<td>100BASE-BX10</td>
<td>100Mb/s</td>
<td>10Km</td>
<td>One single-mode</td>
</tr>
<tr>
<td>1000BASE-LX10</td>
<td>1000Mb/s</td>
<td>10Km</td>
<td>Two single-mode</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Two multimode</td>
</tr>
<tr>
<td>1000BASE-BX10</td>
<td>1000Mb/s</td>
<td>10Km</td>
<td>One single-mode</td>
</tr>
<tr>
<td>1000BASE-PX10</td>
<td>1000Mb/s</td>
<td>10Km</td>
<td>One single-mode</td>
</tr>
<tr>
<td>1000BASE-PX20</td>
<td>1000Mb/s</td>
<td>20Km</td>
<td>One single-mode</td>
</tr>
<tr>
<td>10PASS-TS</td>
<td>10Mb/s*</td>
<td>750m*</td>
<td>Voice grade copper</td>
</tr>
<tr>
<td>2BASE-TL</td>
<td>2Mb/s*</td>
<td>2Km*</td>
<td>Voice grade copper</td>
</tr>
</tbody>
</table>

* Nominal speed and reach

### Key:
- **- Backplane**
- **- Co-axial**
- **- Twin-axial**
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- **- Multimode Fibre**
- **- Single-mode Fibre**
- **- Voice grade copper**
- **- Point to Multipoint Fibre**
10 Gb/s PHYs, Backplane Ethernet

<table>
<thead>
<tr>
<th>PHY Type</th>
<th>Data rate</th>
<th>Distance</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE Std 802.3ak-2004, 10GBASE-CX4</td>
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<td></td>
<td>Copper cable assembly</td>
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<tr>
<td>10GBASE-CX4</td>
<td>10Gb/s</td>
<td>15m</td>
<td></td>
</tr>
<tr>
<td>IEEE Std 802.3an-2006, 10GBASE-T</td>
<td></td>
<td></td>
<td>Twisted-pair</td>
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<tr>
<td>10GBASE-T</td>
<td>10Gb/s</td>
<td>100m</td>
<td></td>
</tr>
<tr>
<td>IEEE Std 802.3ap-2007, Electrical Backplanes</td>
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<td></td>
<td></td>
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<tr>
<td>1000BASE-KX</td>
<td>1000Mb/s</td>
<td>1m</td>
<td>Backplane</td>
</tr>
<tr>
<td>10GBASE-KX4</td>
<td>10Gb/s</td>
<td>1m</td>
<td>Backplane</td>
</tr>
<tr>
<td>10GBASE-KR</td>
<td>10Gb/s</td>
<td>1m</td>
<td>Backplane</td>
</tr>
<tr>
<td>IEEE Std 802.3aq-2006, 10GBASE-LRM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10BASE-LRM</td>
<td>10Gb/s</td>
<td>100m</td>
<td>Two multimode</td>
</tr>
<tr>
<td></td>
<td></td>
<td>220m</td>
<td></td>
</tr>
</tbody>
</table>

Key:
- Backplane
- Twin-axial
- Co-axial
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- Single-mode Fibre
- Voice grade copper
- Point to Multipoint Fibre

Rate (b/s)

Distance (m)
### IEEE Std 802.3as-2006 Frame Extension

**Drivers**
- IEEE Std 802.1ad Provider Bridging
  - Tag in Tag
- IEEE Std 802.1AE MAC Security
  - Cipher block

**Approach**
- Minimal changes
  - Provide for envelope round frame
- No expansion of MAC Client Data
  - Jumbo frames not supported

**Frame sizes supported**
- 1518 decimal – basic frames
- 1522 decimal – Q-tagged frames
- 2000 decimal – envelope frames

<table>
<thead>
<tr>
<th>Size (Octets)</th>
<th>DA</th>
<th>SA</th>
<th>Envelope Prefix</th>
<th>Length/Type</th>
<th>MAC Client Data</th>
<th>Envelope Suffix</th>
<th>FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>6</td>
<td>6</td>
<td>2 to 482 Note 1</td>
<td>2</td>
<td>46 to 1500</td>
<td>0 to 480 Note 1</td>
<td>4</td>
</tr>
</tbody>
</table>

Note 1: Envelope prefix + suffix ≤ 482
Agenda

IEEE 802.3 Overview

IEEE 802.3 Ethernet Physical Layers
Rate, distance, media

IEEE 802.3 Ethernet emerging technologies
New physical layers, new technologies

Conclusion
IEEE 802.3 Ethernet emerging technologies

- Demand for increased bandwidth
  - By connected devices
  - By devices aggregating these devices

- Continuing evolution of Ethernet
  - DTE Power via MDI
  - Energy-efficient Ethernet
  - Mapping to OTN

- Convergence around Ethernet
  - Data Centre Bridging (e.g. FCoE, iWARP)
  - Audio/Video Bridging
IEEE Std 802.3 Ethernet Passive Optical Network (EPON) Architecture

- First mile (subscriber access) technology
  - Point to multipoint fibre media
# IEEE Std 802.3av-2009 10Gb/s EPON Ethernet PHY Types

## PHY Type Data Rate Split Ratio Distance

<table>
<thead>
<tr>
<th>PHY Type</th>
<th>Data rate</th>
<th>Split ratio</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/1GBASE-PRX1</td>
<td>1Gb/s</td>
<td>10Gb/s</td>
<td>1:16</td>
</tr>
<tr>
<td>10/1GBASE-PRX2</td>
<td>1Gb/s</td>
<td>10Gb/s</td>
<td>1:16</td>
</tr>
<tr>
<td>10/1GBASE-PRX3</td>
<td>1Gb/s</td>
<td>10Gb/s</td>
<td>1:32</td>
</tr>
<tr>
<td>10GBASE-PR1</td>
<td>10Gb/s</td>
<td>10Gb/s</td>
<td>1:16</td>
</tr>
<tr>
<td>10GBASE-PR2</td>
<td>10Gb/s</td>
<td>10Gb/s</td>
<td>1:16</td>
</tr>
<tr>
<td>10GBASE-PR3</td>
<td>10Gb/s</td>
<td>10Gb/s</td>
<td>1:32</td>
</tr>
</tbody>
</table>

- 1Gb/s Passive Optical Networks already supported
  - IEEE Std 802.3ah-2004 Ethernet in First Mile
  - 1 Gb/s downstream and upstream
- Bandwidth demands increasing
  - IPTV, VoD
- IEEE Std 802.3av-2009 10Gb/s EPON
  - Symmetric 10 Gb/s downstream and upstream
  - Asymmetric 10 Gb/s downstream, 1Gb/s upstream

---

![Graph showing data rate vs. distance for different PHY types.](image-url)
IEEE Std 802.3ba-2010 40Gb/s and 100Gb/s Ethernet - Generic Market Drivers

- **Computing**
  - Driven by key technologies
    - Internal bus and memory performance
  - System throughput doubles approximately every 2 yrs

- **Core networking**
  - More users, bandwidth, and applications
    - Wide area, ISPs, IXs
    - Increase number of users
    - Increase in bandwidth available; xDSL, xPON, Cable, 3G
    - Increase number of applications; YouTube, Facebook, Netflix
  - Core throughput doubles approximately every 18 months
IEEE Std 802.3ba-2010 40Gb/s and 100Gb/s Ethernet PHY Types

<table>
<thead>
<tr>
<th>PHY Type</th>
<th>Data rate</th>
<th>Distance</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>100GBASE-ER4</td>
<td>100Gb/s</td>
<td>40km</td>
<td>Dual Single-mode fibres</td>
</tr>
<tr>
<td>100GBASE-LR4</td>
<td>100Gb/s</td>
<td>10km</td>
<td>Single-mode fibres</td>
</tr>
<tr>
<td>40GBASE-LR4</td>
<td>40Gb/s</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100GBASE-SR10</td>
<td>100Gb/s</td>
<td>100m</td>
<td>Multiple multimode fibres</td>
</tr>
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<td>40GBASE-SR4</td>
<td>40Gb/s</td>
<td>125m</td>
<td></td>
</tr>
<tr>
<td>100GBASE-CR10</td>
<td>100Gb/s</td>
<td>7m</td>
<td>Copper cable assembly</td>
</tr>
<tr>
<td>40GBASE-CR4</td>
<td>40Gb/s</td>
<td>1m</td>
<td>Backplane</td>
</tr>
<tr>
<td>40GBASE-KR4</td>
<td>40Gb/s</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- ITU-T Optical Transport Network (OTN)
  - Supports 40Gb/s (OTU3) and 100Gb/s (OTU4)
  - Rate and encoding alignment
    - Through liaison relationship with ITU-T
IEEE P802.3bg 40Gb/s Ethernet Single-mode Fibre PMD
IEEE 802.3 100 Gb/s Backplane and Copper Study Group

<table>
<thead>
<tr>
<th>PHY Type</th>
<th>Data rate</th>
<th>Distance</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>40GBASE-FR</td>
<td>40Gb/s</td>
<td>2km</td>
<td>Dual Single-mode fibres</td>
</tr>
<tr>
<td>100GBASE-TBD</td>
<td>100Gb/s</td>
<td>TBD</td>
<td>Copper cable assembly</td>
</tr>
<tr>
<td>100GBASE-TBD</td>
<td>100Gb/s</td>
<td>TBD</td>
<td>Backplane</td>
</tr>
</tbody>
</table>

- **IEEE P802.3bg objectives**
  - Operation over at least 2 km of SMF, optical compatibility with existing carrier client interfaces
    - OTU3/STM-256/OC-768/40G POS
  - Applications
    - Carrier networks equipment interconnection
    - Uplink interconnections into carrier networks

- **IEEE 802.3 100 Gb/s Backplane and Copper Study Group**
  - Study group for 100Gb/s Ethernet Electrical Backplane and Twinaxial Copper Cable Assemblies
IEEE Std 802.3az-2010 Energy-efficient Ethernet Idle operation overview

Normal operation | Low power mode | Normal operation

Updates receiver parameters, timing information and filter coefficients

Signal to receive System to exit low power state

Enables energy efficiency in attached systems
IEEE P802.3bf Time Synchronization
IEEE P802.3.1 Ethernet MIBs

• IEEE P802.3bf Time Synchronization
  – Support for time synchronization protocols such as IEEE Std 802.1AS
  – Small project in IEEE 802.3
    • Addition of new IEEE 802.3 abstract service interface
    • New PHY registers to provide device delays

• IEEE P802.3.1 Ethernet MIBs
  – IETF used to develop Ethernet SNMP MIBs but decided to stop
  – IEEE 802.3 Working Group now has to do work
  – IEEE 802.3.1 is the initial project
    • GDMO MIB from IEEE Std 802.3-2008
    • IEEE Std 802.1AB Annex F (IEEE 802.3 TLVs) SNMP MIB
    • RFCs 2108, 3621, 3635, 3637, 4836, 4837, 4878, 5066
  – Future revisions expected
IEEE 802.3 Ethernet
Bandwidth Assessment Ad Hoc

- Gathering information that will enable an evaluation of the bandwidth needs for Ethernet applications, including, but not limited to, core networking and computing
  - First teleconference held 28th February 2011
  - Refinement of deliverables
Agenda

IEEE 802.3 Overview

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IEEE 802.3 Ethernet emerging technologies
New physical layers, new technologies

Conclusion
Conclusions

• Ethernet is the ubiquitous wired connectivity
  – < 0.01m to 1,000s of kilometres
  – 10Mb/s to 100Gb/s
    • Link Aggregation
      – Backplane to fibre (and everything in between)
  • New speeds, media, features and applications reinforce this
    – 40Gb/s and 100Gb/s
    – Energy-efficient Ethernet
  • Continued convergence on Ethernet
    – Data Centre Bridging
    – Audio/Video Bridging
IEEE 802.3 Standards

• IEEE Std 802.3™-2008 Ethernet Access Method and Physical Layer Specifications*
  
  – IEEE Std 802.3av™-2009 10Gb/s EPON*
  – IEEE Std 802.3bc™-2009 Ethernet TLVs *
  – IEEE Std 802.3at™-2009 DTE Power Enhancements *
  – IEEE Std 802.3ba™-2010 40Gb/s and 100Gb/s Ethernet *
  – IEEE Std 802.3az™-2010 Energy-efficient Ethernet

• Available through Get IEEE 802
  http://standards.ieee.org/getieee802/802.3.html

• Working group web site
  http://www.ieee802.org/3/